Arch. Dis. Childh., 1968, **43**, 310.

Prediction of Height from Foot Length: Use of Measurement in Field Surveys

INGRID H. E. RUTISHAUSER

From the Medical Research Council Infantile Malnutrition Unit, Mulago Hospital, Kampala, Uganda

Investigators have studied the relation between height and the length of various long bones (Dupertius and Hadden, 1951; Trotter and Gleser, 1952, 1958; Zorab, Prime, and Harrison, 1963), and have found good correlation between these measurements. The accurate measurement of height under field survey conditions is extremely difficult, but can provide valuable information. In this type of survey, measurements have frequently to be made by staff with a minimum of training in the techniques used, and the measurement of any of the long bones would not be a practicable alternative to the measurement of height. A measurement of foot length can, however, be made very simply and accurately. This paper describes the method of measurement and gives details of the correlation between foot length and height in three groups of African children of different ethnic origin.

Material and Methods

Measurements of height and foot length were made in 683 African children aged 6 years or under. 60 were of Bantu, 328 of Nilotic, and 295 of Nilohamitic origin. Recumbent length was measured in the yougest children using a lengthboard graduated in millimetres, and standing height in children aged over 2 years using a 'Gneupel' standard anthropometric rod. All measurements of height were made by the author. Foot length was measured in the following way. The sole of the child's left foot was first cleaned using a piece of cotton-wool moistened with surgical spirit or other cleansing agent; it was then placed firmly on a large ink pad of the type that can be bought from stationers and printers, making sure the foot and toes were fully extended. In this study a pad 12×25 cm. was found to be adequate. With the child standing or supported on his right leg, the left foot was placed on a piece of paper on a small stool, and just sufficient pressure applied to ensure good contact between the sole of the foot and the paper. The footprints thus obtained were measured later at leisure. This was done as shown in Fig. 1, using a pair of dividers and measuring the distance between the centre of the back of the heel and the tip of the longest toe, and reading off the distance against a centimetre scale.

Received September 18, 1967.

Results

Table I gives the correlation coefficients (r) and the regression equations for height (y) on foot length (x) calculated from the data, together with the standard deviations of error (Sr) incurred by using the regression equations as an estimate of height.

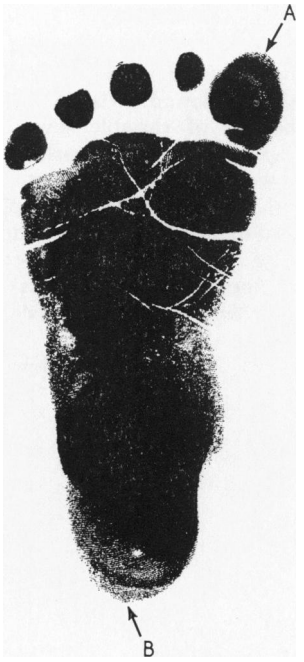

FIG. 1.—*A typical footprint showing the points A (tip of the longest toe) and B (centre of the back of the heel), the distance between which was used as a measure of foot length.*

The correlation coefficients for the data of all three groups are similar (0·90–0·98) and indicate a highly significant ($p<0·001$) degree of association between height and foot length.

Height is calculated from the regression equation by inserting the value for foot length in the equation. Thus, the height for a Nilotic girl with a foot length of 10 cm. is given by the equation:

Height (cm.) $= (6·23 \times 10)+4·66 = 66·96$ cm.

The standard deviations of error (Sr) of the estimation of height from foot length are of the same order as those found by Trotter and Gleser (1958) for American adult men, and those found by Zorab *et al.* (1963) for 13-year-old children, for the estimation of height from the length of the long bones.

The 95% confidence limits $\pm(1·96 \times Sr)$ for individual values in the Nilotic group are shown in Fig. 2. For the Bantu and Nilotic groups the standard deviations of error are somewhat greater for the girls than for the boys, whereas the reverse is the case in the Nilohamitic group.

The regression equations for all three groups are very similar and the slopes of the regression lines do not differ significantly either between the different groups or within each group. In each group, however, at any given foot length within the range 8–16 cm., the estimated height of the girls is greater than that of the boys by an average of 0·97 cm. for the Bantu, 0·60 cm. for the Nilotes, and 1·46 cm. for the Nilohamites, with respective standard errors of 0·38, 0·05, and 0·22 cm.

TABLE I

Correlation Coefficients (r) and Regression Equations for Height (y) on Foot Length (x), together with Standard Deviations of Error (Sr) incurred by using the Regression Equation as an Estimate of Height

Group	Sex	No.	r	Regression Equation	Sr
Bantu	M	29	0·96	$y = 5·50x+8·64$	±2·53
	F	31	0·90	$y = 5·89x+4·91$	±3·60
Nilotic	M	157	0·98	$y = 6·19x+4·54$	±3·02
	F	171	0·97	$y = 6·23x+4·66$	±3·52
Nilohamitic	M	148	0·97	$y = 6·17x+4·58$	±3·55
	F	147	0·97	$y = 6·42x+3·04$	±3·32

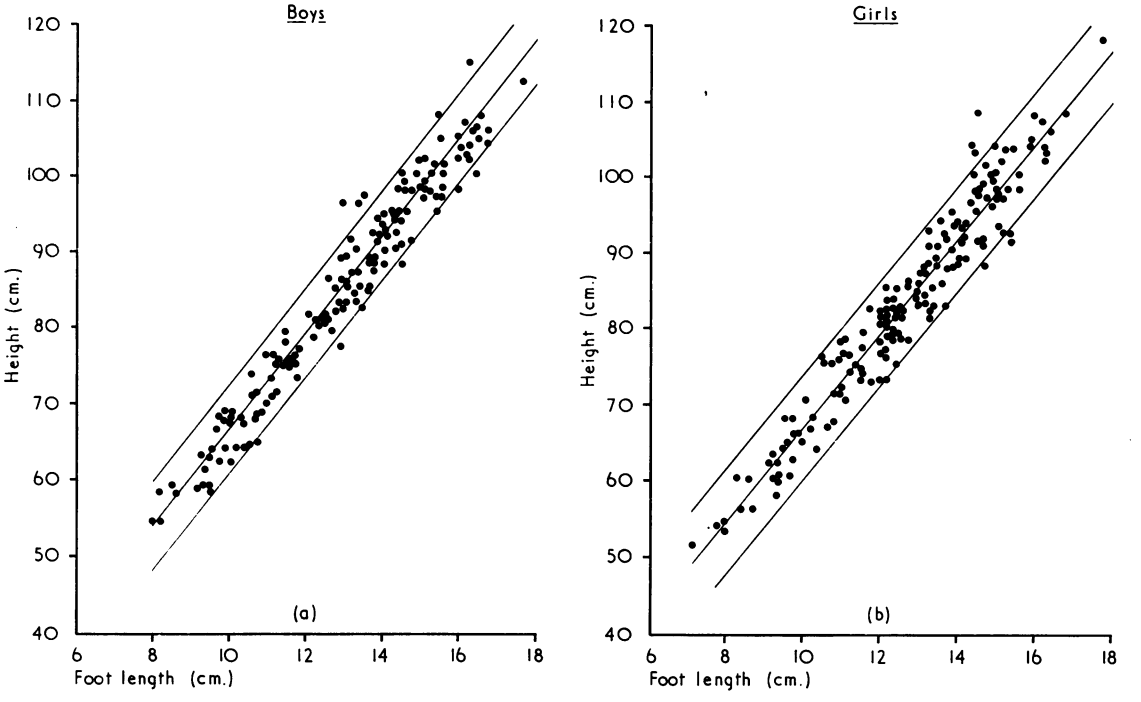

FIG. 2.—*The 95% confidence limits for the estimation of height from foot length in Nilotic children; (a) boys, (b) girls.*

The correlation coefficients, regression equations, and standard deviations of error given in Table I apply only to the pooled data for children from birth to 6 years, and not to children within single-year age-groups. Table II gives the correlation coefficients (r), regression equations for height (y) on foot length (x), and standard deviations of error (Sr) for single-year age-groups calculated from the Nilotic data.

The correlation coefficients are lower (0·75–0·93) but still indicate a highly significant ($p<0·001$) degree of association between height and foot length, and the standard deviations of error are of the same order as for the pooled data. The regression equations differ for each age-group, but there is no significant difference in the slopes of the regression lines at different ages or for boys and girls at the same age.

TABLE II

Correlation Coefficients (r) and Regression Equations for Height (y) on Foot Length (x), together with Standard Deviations of Error (Sr) at Different Ages

Age-group	Sex	No.	r	Regression Equation	Sr
<1 year	M	34	0·88	y = 5·01x + 15·21	±3·26
	F	34	0·92	y = 4·76x + 17·90	±2·35
1 year +	M	32	0·86	y = 3·92x + 31·18	±2·63
	F	36	0·75	y = 3·68x + 34·19	±3·10
2 years +	M	20	0·81	y = 4·01x + 33·56	±2·87
	F	32	0·93	y = 4·22x + 30·63	±1·95
3 years +	M	26	0·86	y = 5·59x + 13·75	±3·92
	F	23	0·85	y = 4·94x + 22·93	±3·54
4 years +	M	25	0·92	y = 5·28x + 18·03	±2·16
	F	22	0·81	y = 4·74x + 26·81	±3·70
5 years +	M	16	0·84	y = 4·23x + 37·67	±3·80
	F	22	0·80	y = 4·98x + 26·88	±3·47

Conclusions

Although these results show that the estimation of height from foot length in children has confidence limits of estimation of the same order as those found for the estimation of height from long bones in adults, these limits in children involve greater percentage errors, and an estimate of height from foot length in any individual is unlikely to be more accurate than the measurement of height made by a good observer in a field survey. Community surveys in general, however, are not concerned with individuals but with the group as a whole, and in such surveys it is likely that the estimation of height from foot length may, in fact, be more accurate than the measurement of height by an untrained observer. First, the accurate measurement of height in an uncooperative child is extremely difficult, if not impossible, whereas foot length by the method described can be measured simply and accurately. Secondly, the errors in estimation of height from foot length will tend to cancel out in a large number of individuals, whereas in our experience those of any one observer measuring height are likely to be in the same direction.

In young children, particularly, there is no doubt that the measurement of foot length is considerably easier, more accurate, and less time consuming than the measurement of height. The measurement may also be of use in the estimation of stature in deformed children, as previously suggested by Zorab *et al.* (1963) for the estimation of height from tibial length.

Summary

A highly significant degree of correlation between measurements of height and foot length was found in three groups of African children of different ethnic origin. In young children the estimation of height from foot length could be of value both in field surveys and in the case of deformity.

I am grateful to my sister, Miss S. C. B. Rutishauser, for invaluable help with the analysis of the data, and to Professor R. A. McCance for much advice.

References

Dupertius, C. W., and Hadden, J. A., Jr. (1951). On the reconstruction of stature from long bones. *Amer. J. phys. Anthrop.*, **9**, 15.

Trotter, M., and Gleser, G. C. (1952). Estimation of stature from long bones of American Whites and Negroes. *ibid.*, **10**, 463.

——, and —— (1958). A re-evaluation of estimation of stature based on measurements of stature taken during life and of long bones after death. *ibid.*, **16**, 79.

Zorab, P. A., Prime, F. J., and Harrison, A. (1963). Estimation of height from tibial length. *Lancet*, **1**, 195.